Testimony of

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Madam Chair and members of the Subcommittee. I am Don Anderson, Senior Scientist in the Biology Department of the Woods Hole Oceanographic Institution, where have been active in the study of red tides and harmful algal blooms (HABs) for over 25 years. I am here to provide the perspective of an experienced scientist who has investigated many of the HAB phenomena that affect coastal waters of the United States and the world. I am also Director of the U.S. National Office for Marine Biotoxins and Harmful Algal Blooms, and have been actively involved in formulating the scientific framework and agency partnerships needed to attack the HAB problem in an efficient and productive manner. Thank you for the opportunity to acquaint you with the national problem of Harmful Algal Blooms and the steps the scientific community is taking to address it.

Background.

Blooms of toxic or harmful microalgae, commonly called "red tides", represent a significant and expanding threat to human health and fisheries resources throughout the U.S. and the world. They take many forms, ranging from massive accumulations of cells that discolor the water, to dilute, inconspicuous, but highly toxic populations. The impacts include: mass mortalities of wild and farmed fish and shellfish; human intoxications and death from the consumption of contaminated shellfish or fish; alterations of marine food webs through adverse effects on larvae and other life history stages of commercial fish species; and mass mortalities of marine mammals, seabirds, and other animals. We now know that many of the toxins produced by HAB species affect reproduction and survival throughout the food web, moving from level to level in a manner analogous to the transfer of pollutants such as DDT or

PCBs. The effects on entire coastal ecosystems remain poorly understood but are clearly significant.

Recent outbreaks of an organism called *Pfiesteria* focused public and political attention on a specific HAB episode in the Chesapeake Bay that was alarming and disturbing to many, yet there are numerous other HAB problems in the U.S. that are at least as worrisome, that impact vastly larger areas, but that are presently not receiving appropriate scientific attention. For example, in the same month that 50,000 fish were killed by *Pfiesteria* in Maryland last fall, (resulting in tremendous media and political attention and a significant flow of funds), *14,000,000* fish died during a red tide along the Texas coast that never made the national news or the front page of the Washington Post. In both the northeast and the northwest, *thousands of miles* of coastline are closed because of the threat of toxic shellfish, some of it permanently. These are but two examples to support the argument that funding should be distributed so as to address <u>all</u> HAB problems, not just the one that is closest to Washington D.C. or that happens to attract attention in a given year.

In the United States, the most significant economic and public health problems related to toxic and harmful algae are:

- **Paralytic shellfish poisoning (PSP)**. This is a life threatening syndrome associated with the consumption of shellfish or certain fish containing a class of algal neurotoxins called the saxitoxins. Symptoms are neurological and their onset is rapid. The most severe cases result in respiratory arrest within 24 hours of consumption of the toxic shellfish. There is no antidote. PSP is prevented by large-scale proactive monitoring programs (assessing toxin levels in mussels, oysters, scallops, clams) and rapid closures to harvest of suspect or demonstrated toxic areas. The regions affected include all coastal New England states and much of the west coast from Alaska to California (Fig. 1). This problem has also extended to offshore areas in the northeast such as Georges Bank.

- **Neurotoxic shellfish poisoning (NSP)**. This intoxication causes severe gastrointestinal and neurological symptoms in consumers of shellfish which have accumulated a class of algal toxins called the brevetoxins. Another impact is associated with airborne toxin in sea spray, which results in respiratory asthma-like symptoms in those near the shore. Marine mammal mortalities, notably the Florida manatee, have also been linked to these red tide toxins. No human deaths have been reported from NSP, but the syndrome is quite debilitating. NSP is prevented by monitoring programs and closure of affected areas. Fish kills and aerosol problems are managed through beach clean-up efforts and health advisories. The regions affected include Florida, Louisiana, Mississippi, and Texas, and occasionally on the coast of the Carolinas (Fig. 2).

- **Amnesic shellfish poisoning (ASP).** The algal toxin responsible for ASP was first identified in Canada in 1987, and has been a problem for the United States Pacific coast states since 1991. This sometimes fatal illness is so named because one of its most severe symptoms is the permanent loss of short-term memory. The ASP toxin, domoic acid, has been detected in shellfish from both the west and east coasts of the U.S. and the Gulf of Mexico (Fig. 3). The name "ASP" understates the severity of this problem, as it is now known that domoic acid also accumulates in fish, crab, and other fisheries resources.

- **Ciguatera fish poisoning (CFP).** This is a malady associated with algal toxins called ciguatoxins that accumulate in tropical fish flesh. Victims experience gastrointestinal, neurological, and cardiovascular symptoms. Paralysis and death have been documented, but symptoms are usually less severe, but nevertheless debilitating. Recovery time is variable, and may take years. There is no antidote, supportive therapy is the rule, and survivors recover. Absolute prevention of intoxication depends upon complete abstinence from eating any tropical reef fish, since there is currently no practical way to measure ciguatoxin in any seafood product prior to consumption. CFP is a problem in virtually all sub-tropical to tropical United States waters, including Florida, Hawaii, Guam, United States Virgin Islands, Puerto Rico, and many Pacific Territories (Fig. 4).

- **Mortalities of farmed salmon.** Aquaculture facilities in the Pacific Northwest (Fig. 5) are frequently affected by blooms of toxic algae, resulting in massive mortalities of farmed fish, especially salmonids. As the nation's finfish aquaculture industry grows, as is occurring in Maine, for example, fish mortalities from HABs will undoubtedly increase.

- **Recurrent brown tides.** Blooms of two tiny algal species unknown to science a decade ago have caused brown tides Rhode Island, New Jersey, Long Island, and in the Laguna Madre system of southern Texas. The northeast bloom caused mass mortalities of mussel populations, the destruction of the bay scallop industry, and reduction of eelgrass beds (a prime habitat or nursery for many marine species). The Laguna Madre brown tide lasted for 7 years and also affected eelgrass habitat and ecosystem structure.

- **The *Pfiesteria* complex.** *Pfiesteria* and closely related dinoflagellates have been linked to massive fish kills and to living fish with open, bleeding lesions or other abnormalities. In the laboratory, human exposure to aerosols from toxic *Pfiesteria* cultures has caused short- and long-term neurotoxic symptoms, and fishermen and others working in or exposed to waters containing *Pfiesteria* have complained of similar problems, exemplified in the worst cases as a dramatic loss of neurocognitive ability. *Pfiesteria*-like species have been identified in North Carolina, Florida, and in several states bordering the Chesapeake (Fig. 5).

- **Blooms of macroalgae (seaweeds).** As with the microalgae, seaweed growth is enhanced in response to nutrient enrichment associated with coastal eutrophication. Opportunistic macroalgal species outcompete, overgrow, and replace seagrass and coral reef ecosystems. Once established, seaweed blooms may remain in an environment for years to decades until nutrient supplies decrease. Negative effects include reduced light availability to seagrasses and reef systems, leading to lower productivity, habitat loss from hypoxia/anoxia, and eventual die-off of sensitive species. Seaweed blooms are a problem throughout the U.S., but are especially serious in southern Florida and other warmer waters.

Economic and Societal Impacts

HABs have a wide array of economic impacts, including the costs of conducting routine monitoring programs for shellfish and other affected resources, short-term and permanent closure of harvestable shellfish and fish stocks, reductions in seafood sales, mortalities of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs, bottom-up impacts on tourism and tourism-related businesses, and medical treatment of exposed populations. These economic losses are difficult to estimate, and fluctuate dramatically from year to year. Other impacts that are difficult to quantify include the collateral avoidance of safe seafood products or the value of fisheries resources that are not developed due to persistent toxicity or to the expectation of future toxicity. An estimate of HAB costs to the entire United States is not yet available, but preliminary analyses indicate an average annual impact of over $45 million over the interval 1987-1993. (Losses from isolated, individual events can sometimes equal or exceed the annual averages, as in 1997 when the *Pfiesteria* outbreaks resulted in a collapse of Chesapeake Bay seafood sales and boat charters, with losses to watermen, seafood dealers and restaurants exceeding $43 million). The national estimate given above does not include the value of fisheries that are not developed or exploited due to the threat of persistent toxicity, nor does it reflect "multiplier" effects that are often used to account for the manner in which money transfers through a local economy. If multipliers are used, the estimate of HAB economic impacts in the Unites States easily exceeds $100 million per year or $1 billion per decade.

Recent Trends

The nature of the HAB problem has changed considerably over the last two decades in the United States. Virtually every coastal state is now threatened by recurrent harmful or toxic algal species, whereas 25 years ago, the problem was much more scattered and sporadic (Fig. 6). Few would argue that the number of toxic blooms, the economic losses from them, the types of fisheries resources affected, the size of the areas affected, and the number of toxins and toxic algal species have all increased dramatically in recent years in the United States and around the world .

A common assumption is that pollution or other human activities are responsible for this expansion. On close inspection, however, some of the “new” HAB outbreaks in the United States can be explained by natural phenomena such as storms or long distance transport by ocean currents. Other bloom events may simply reflect indigenous populations that are discovered because of better detection methods and more observers. Scientists are much better at detecting known toxins and finding new ones than ever before, in part because analytical instruments and methods are vastly improved and because there is rapid and efficient communication throughout the world. The appearance of ASP along the United States west coast after 1991 is a good example of this, as the diatom species that produce the ASP toxin are now known to have been present in those waters many years before the 1991 discovery. Humans have contributed to the global HAB expansion by transporting toxic species in ship ballast water or by dramatically increasing aquaculture activities, leading to increased monitoring of product quality and safety and revealing indigenous toxic algae that were probably always there.

The linkage to pollution should not be ignored, however, as the input of sewage to coastal waters will stimulate "background" populations of algae by supplying them with nutrients, allowing the populations to grow faster and longer. Harmful or toxic species will thus be more abundant and more noticeable. Some scientists even argue that the nutrients that humans supply to coastal waters are delivered in proportions which differ from those that naturally occur, such that we then alter the species composition of the algae by favoring certain groups (including HAB species) better adapted to our nutrient supply ratios. A prominent example of how pollution has been linked to harmful blooms is with the dinoflagellate *Pfiesteria*. That organism and many closely related fish-killing species seem to thrive in polluted waters. Some view the sudden appearance of Pfiesteria and other HAB species as a visible and dramatic warning of the dangers that arise from decades of abuse of estuarine and coastal waters - the canary in the coal mine analogy.

It is clear then that the expansion of the HAB problem is in part a matter of perception or increased awareness, and in part a matter of the actual growth of the problem. In other words, years ago we were not aware of the size or complexity of the HAB problem, but as we became better at detecting toxins and recognizing HAB phenomena, we more clearly defined the extensive boundaries of the problem. On top of this apparent increase there has been genuine growth in the problem due to such factors as pollution, aquaculture, or accidental species dispersal through human activities.*The fact that some of the increase is simply a result of better detection or more observers does not diminish the seriousness of the HAB problem, however.* It's big and it's growing and that trend is all the more worrisome in light of rapid population growth in the coastal zones of the country and our heavy dependence on near-shore waters for economics, nutrition, and recreation.

Management Issues

Recent outbreaks of an organism called *Pfiesteria* focused public and political attention on a specific HAB episode in the Chesapeake Bay that was alarming and disturbing to many, yet there are numerous other HAB problems in the U.S. that are at least as worrisome, that cover vastly larger areas, but that are presently not receiving appropriate scientific attention. Historically, there have been numerous "HAB crises" similar to the *Pfiesteria* hysteria, and the lessons learned about the federal and state response to those events provide useful guidance to the present. For example, in 1972 a massive red tide brought PSP to many areas of New England with no history of shellfish toxicity. In 1985, the brown tide struck Long Island, New Jersey and Rhode Island, causing significant ecosystem and fisheries impacts, including the destruction of the Long Island bay scallop industry. In 1991, ASP toxin was discovered along much of the west coast, necessitating quarantines of multiple fisheries resources. In 1987, a red tide swept into North Carolina waters for the first time, causing an estimated $20 million dollars in damage to the tourist and shellfish industries. As with *Pfiesteria,* the response to these and many other past HAB outbreaks was to provide an immediate infusion of funds, personnel, and resources. In the ensuing years, however, that support dwindled and often disappeared as the initial impact of the unexpected outbreaks faded from memory. The algal blooms that were the source of the initial problems have often recurred year after year, but many of the research teams established to attack them have been disbanded due to the "boom and bust" nature of the funding response.

Recognizing that we needed to take an active role in changing this inefficient allocation of resources, the HAB community organized itself and formulated a national program and science agenda. We believe an effective management program for HABs should have the following elements, some of which are in place and some of which remain to be implemented:

1. Inter-agency coordination, government leadership, and a framework for action.

The list of U.S. agencies and programs involved with algal blooms is long and diverse. There is a clear need for coordination to avoid the duplication of effort and omissions in coverage that are often associated with multi-agency, multi-disciplinary programs. There is also a need for planning so that limited resources are directed to the highest priority topics. Much has been accomplished in this regard. As a first step, the HAB community worked with NOAA to formulate a *National Plan for Marine Biotoxins and Harmful Algae* (Anderson et al. 1993), a planning document which outlines specific objectives required to address HAB management needs. These address toxins, their impacts, detection and modes of action, the ecology and oceanography of HAB species, fisheries and food web issues, and the prevention, control and mitigation of blooms and their impacts. The *National Plan* now serves as the foundation for many national HAB activities.

Inter-agency coordination is provided by an *ad hoc* Inter-Agency Task Force on Marine Biotoxins and Harmful Algae - a group of program managers from a variety of federal agencies concerned with HABs and their impacts. The Task Force meets periodically to review progress on the *National Plan* and to form partnerships to facilitate new program implementation. An additional action was the creation of a National Office for Marine Biotoxins and Harmful Algal Blooms at the Woods Hole Oceanographic Institution, which I direct. This office serves as a contact point for requests for information on HABs, both technical and general, from the public, journalists, politicians, and agency officials. The office collects data annually on HAB outbreaks in the U.S., maintains a heavily used Web page, and organizes national workshops and other HAB community activities. Overall leadership for the national HAB program has been through NOAA's National Ocean Service (NOS) and Coastal Ocean Program (COP) which have done a commendable job creating agency partnerships and fulfilling the objectives of the *National Plan*. In my opinion, these aspects of a national HAB program are in place, and the legislation before you will sustain that leadership and momentum.

2. Competent research teams and infrastructure.

The second need is for skilled research teams with the equipment and facilities required to attack the complex scientific issues involved in HAB phenomena. Since HAB problems facing the U.S. are diverse with respect to the causative species, the affected resources, the toxins involved, and the oceanographic systems and habitats in which the blooms occur, we need *multiple* teams of skilled researchers and managers *distributed throughout the country*. This argues against funding that ebbs and floods with the sporadic pattern of HAB outbreaks or that focuses resources in one region while others go begging. *I cannot emphasize too strongly the need for an equitable distribution of resources that is consistent with the scale and extent of the national problem, and that is sustained through time.* This is the only way to keep research teams intact, forming the core of expertise and knowledge that leads to scientific progress. To achieve this balance, we need a scientifically based allocation of resources, not one based on political jurisdictions. This is possible if we work within the guidelines of the *National Plan* and with the inter-agency effort that has been guiding its implementation.

3. Targeted funding programs.

The third need is for targeted funding programs which recognize that management of HAB phenomena requires expertise in many disciplines ranging from toxicology and public health to oceanography and fisheries ecology. No single funding program or agency can address all of the issues identified in the *National Plan*. One program is already in place called ECOHAB (The ECology and Oceanography of

Harmful Algal Blooms), the first federal interagency research program to support fundamental research on the environmental factors responsible for bloom development, persistence, and decline. ECOHAB is coordinated through NOAA in partnership with the National Science Foundation, the United States Environmental Protection Agency, the Office of Naval Research, and the National Aeronautics and Space Administration.

Funding for ECOHAB is modest, but it is administered in a scientifically rigorous manner that maximizes research progress. Currently, HAB dynamics in two regions of the U.S. are being investigated (the Gulf of Mexico and the Gulf of Maine), while smaller investigations of several other U.S. HAB species are also supported. However, since HAB problems affect virtually the entire U.S. coast, other regional programs are needed. ECOHAB support for regional studies must be expanded, and this will require a commitment of resources well in excess of those currently available and a decade or more of sustained funding. The bill before your committee seeks to sustain and supplement ECOHAB support, and I fully endorse that action.

ECOHAB cannot address all of the HAB research needs, so we envision a parallel series of programs which focus on other aspects of the national problem. Research on management, mitigation, and control is a critical need in this respect. Last year, NOAA took the lead in sponsoring a series of workshops on options for reducing HAB impacts in U.S. waters. The resulting report (Boesch et al., 1997) calls for improved precautions for the protection of human health, more concerted efforts to manage activities which may cause HABs, and renewed consideration of strategies to control blooms once they occur. The expert panel convened for this assessment recommended that a new multi-agency initiative on HAB management, mitigation, and control should be implemented and resources provided to support species- and region-specific approaches for reducing or eliminating HAB impacts. I fully concur with this recommendation, and emphasize that these important topics will not be addressed by the ECOHAB program as it is currently defined.

Another program need involves epidemiology and public health**.** Toxin production by several HAB species can seriously impact wildlife and pose threats to human health, yet our epidemiological and pharmacological knowledge of these toxins is limited. Quite simply, there is insufficient Federal support currently to address all toxins, toxic species, modes of action, detection methods, and impacts on coastal resources, food webs and humans. Acute single-dose lethality of toxins has been studied extensively, but chronic and/or repeated exposure to marine seafood toxins, which is a more realistic phenomenon, has not been adequately examined. There are also new toxins, such as those associated with the recent *Pfiesteria* outbreaks, whose health effects remain uncharacterized. These knowledge gaps prevent researchers from devising antidotes or effective treatments which may alleviate or lessen the symptoms.

These deficiencies should be addressed by a funding initiative targeting the medical aspects of HAB toxins, emphasizing the need to identify primary tissues of toxicological action in animals and man, and to develop in vitro models that reflect the primary toxicologic action for the major HAB toxins. Similarly, statistical data collection on human exposure, intoxication duration, and number of incidences are limited and incomplete. Many cases of intoxication are not reported, or are reported inadequately with little documentation. Ongoing programs in this area are all vastly underfunded and cannot consider all taxa and toxins produced. I see solid justification for a program on epidemiology and public health aspects of HABs.

4. A “rapid response” capability with coordinated public risk communication.

A final program need reflects the fact that when unexpected HAB outbreaks occur, the state and federal response has often been confused, uncoordinated, slow, and contentious. Illnesses and deaths from marine biotoxins have occurred, and public confidence in seafood safety continues to erode. What is needed is a “rapid response” capability to allow scientists and regulators to investigate unexpected HAB outbreaks. This requires both funding and leadership. A related need is for a public risk communication strategy to provide up-to-date, accurate information on HAB outbreaks for the public, journalists, the medical community, and the fisheries industry. In many cases, the economic costs of an HAB far exceeds the realistic or direct impact of the problem. This “halo” effect results when fisheries resources that are perfectly safe are avoided by skittish and poorly informed consumers. These two elements could be stand-alone initiatives, or could be components of a program on management, mitigation, and control.

Overview

The diverse nature of HAB phenomena and the hydrodynamic and geographic variability associated with different outbreaks throughout the U.S. pose a significant constraint to the development of a coordinated national program. Nevertheless, the combination of planning, coordination, and a highly compelling topic with great societal importance have set the stage for cooperation between officials, government scientists and academics in a sustained attack on the HAB problem. The rate and extent of progress from here will depend upon how well different federal agencies can work together, how much funding support is provided, and on how effectively the skills and expertise of government and academic scientists can be targeted on priority topics. In this testimony, I have tried to provide an overview of the status of the HAB problem, emphasizing the challenges as well as the significant progress that has been made in formulating and implementing a national program. The HAB community has matured scientifically and politically, and is well-positioned to undertake the new challenges inherent in an expanded national program. This will be successful only if a coordinated, multi-faceted interagency effort can be implemented to focus research personnel, facilities, and financial resources on the diverse goals of our comprehensive national strategy.

Madam Chair, that concludes my testimony. I would be pleased to answer any questions that you or other members may have.

Respectfully submitted,

Donald M. Anderson, PhD

Literature citations:

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Figure 1. PSP events in the United States of America

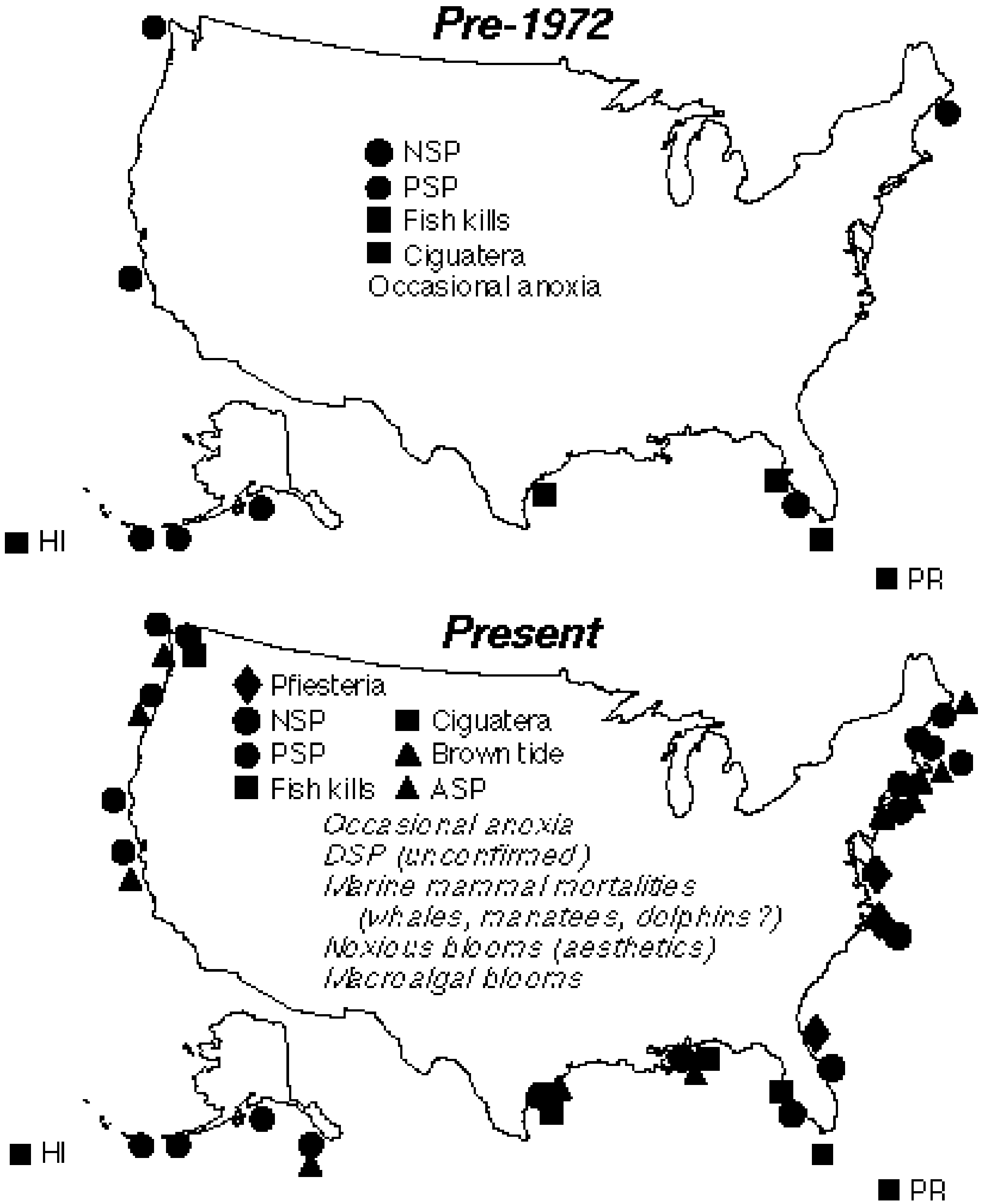
Figure 2. NSP events in the United States of America

Figure 3. ASP events in the United States of America

Figure 4. Ciguatera Fish Poisoning (CFP)

Figure 5. Animal and Plant Mortalities

Figure 6. Spread of Harmful Algal Blooms in United States Coastal Waters



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